Growth Response of White Spruce [*Picea glauca* (Moench) Voss] in Denali National Park under Warming Climate

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Figure 1. *Picea glauca* (White spruce)

Introduction

Background

- In subarctic mountains such as Denali National Park and Preserve (DNP), vegetation shifts from alpine tundra to boreal forests caused by recent climate change are a potential threat to plant conservation and indirectly to animal habits and diversity, which could affect the experience of visitors who wish to see wildlife[1].
- The growth rate of *Picea glauca* (white spruce) could decrease by climate change due to drought stress, which might lead to species elimination[2].
- The shift of *P. glauca* towards a higher elevation would require its seedlings not only to adapt to new abiotic harsh conditions, but also to compete with other plant species that are already present.

Hypotheses

- Growth of *Picea. glauca* is limited by cold temperatures; thus, warming will positively affect spruce seedlings as long as no drought stress occurs.
- Harsh habitats have a negative effect on the establishment of seedlings.
- Interactions between *P. glauca* and neighboring plants are always competitive, but harsh environments can trigger less competitive or even facilitative effects.

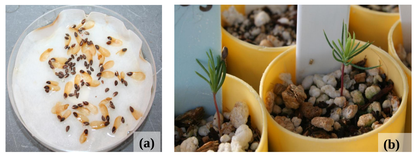

Figure 2. Seed preparation. (a) Germination. (b) A month old seedlings.

Methods

- A total of 171, *P. glauca* seedlings whose seeds originated in DNP and were raised in the UAF greenhouse, were transplanted under 12 treatments in June 2010.

Table 1. Sites, treatments and survival in September 2011. In the "high" treatments, temperature was warmed by small greenhouses. Above ground neighboring plants were removed in "Removal" plots.

Habitat	Temperature	Neighbors	Site#	Original	Mortality	Survived
Above	Control	Control	a	15	4	11
treeline,	Control	Removal	b	14	0	14
ridge	High	Control	c	14	0	14
(1169m)	High	Removal	d	14	0	14
		Above site total		57	4	53
Near	Control	Control	e	15	0	15
treeline,	Control	Removal	f	14	0	14
tundra	High	Control	g	14	1	13
(670m)	High	Removal	h	14	0	14
		Near site total		57	1	56
Below	Control	Control	k	15	2	13
treeline,	Control	Removal	l	14	0	14
forest	High	Control	i	14	8	6
(618m)	High	Removal	j	14	0	14
		Below site total		57	10	47
		Total		171	15	156

Figure 3. Study sites and treatments in Camp Denali, DNP. (a) A greenhouse for a high temperature treatment and (b) seedlings at the outside site (control) above treeline. (c) Competition test by removal of neighboring plants.

- In September 2011, data was collected from 156, one-and-a-half-year-old surviving seedlings (n = 156, 91% survived) as follows;

Non-destructive size measurements (Relative growth rate, RGR)
- Height, number of leaves and maximum length of leaves
- $RGR_{size} = (\ln Size_{final} - \ln Size_{initial}) / (day_{final} - day_{initial})$
  (initial= size in June, final=size in September, Durations = 90 ~ 93 days)

Maximum gross photosynthesis rates
- Net photosynthesis (at1500µmol m^{-2} s^{-1}) and dark respiration rates (0µmol m^{-2} s^{-1}) under CO_2 concentration of 400 ppm by Licor 6400XT photosynthesis system.
- Gross photosynthesis = Net photosynthesis – Respiration (-value)

Destructive measurements (leaf sampling for C/N analyses)
- 10-15 leaves from subsamples (4-5 seedlings with greatest number of leaves in each treatment, $n_t = 59$)
- Concentrations of N and C, and contents of ^{15}N and ^{13}C by mass spectrometry analyses at the Alaska Staible Isotope Facility at UAF.

Results

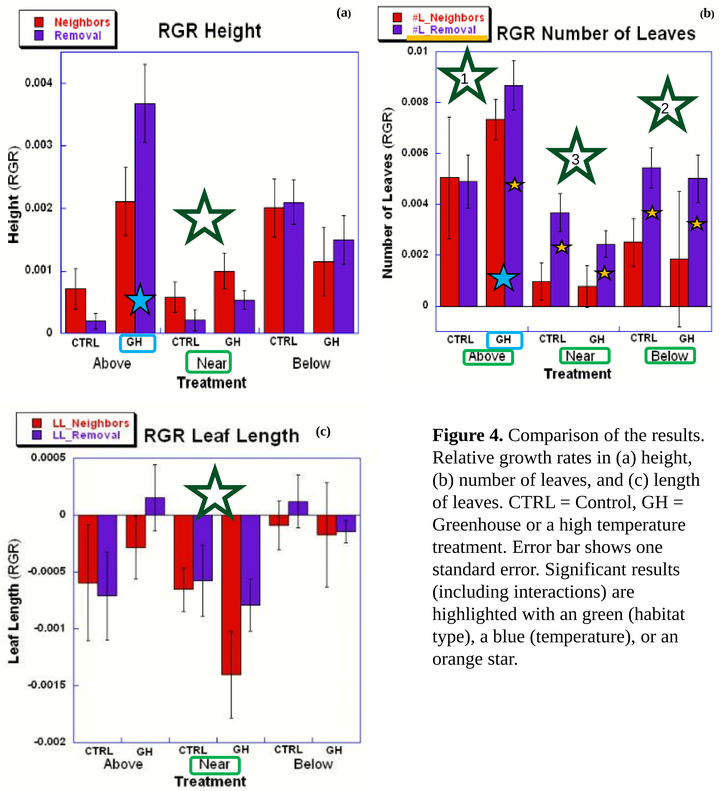

Figure 4. Comparison of the results. Relative growth rates in (a) height, (b) number of leaves, and (c) length of leaves. CTRL = Control, GH = Greenhouse or a high temperature treatment. Error bar shows one standard error. Significant results (including interactions) are highlighted with an green (habitat type), a blue (temperature), or an orange star.

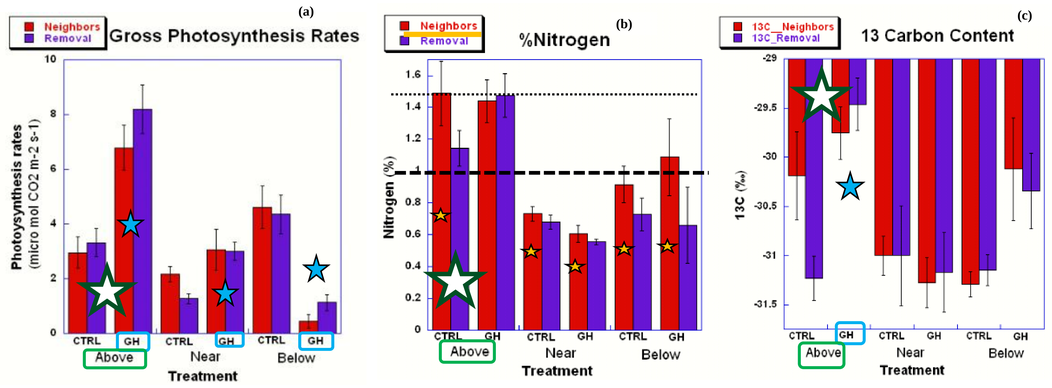

Figure 5. Comparison of the results . (a) Gross photosynthesis rate, (b) N content and (c) ^{13}C content. CTRL = Control, GH = Greenhouse or a high temperature treatment. Error bar shows one standard error. Significant results (including interactions) are highlighted with an green (habitat type), a blue (temperature), or an orange star. Dotted lines in (a) indicate deficiency levels of N (1.45% > moderate and 1.05% > severe)

Table2. Results of statistics (ANOVA). The interactions between the treatments were shown e.g. H*T (habitat type and temperature). Significant differences were shaded.

(Shaded: P< 0.05)

	Factor													
	Habitat type (H)		Temperature (T)		Removal (R)		H*T		H*R		T*R		H*T*R	
	Ndf: 2	Ddf:153	Ndf: 1	Ddf:154	Ndf: 1	Ddf:154	Ndf: 5	Ddf:150	Ndf: 5	Ddf:150	Ndf: 3	Ddf:152	Ndf: 11	Ddf:145
	F	P	F	P	F	P	F	P	F	P	F	P	F	P
(1)RGR Height †	9.510	0.0001	11.256	0.001	0.230	0.633	15.428	<0.0001	1.958	0.145	5.047	0.0262	1.426	0.244
(2) RGR # of leaves †	28.142	<0.0001	1.791	0.183	9.221	0.0028	3.702	0.027	1.474	0.232	0.501	0.480	0.712	0.493
(3) RGR Leaf length ‡	7.099	0.0011	0.190	0.664	0.606	0.438	1.723	0.182	0.179	0.837	0.060	0.807	0.973	0.380
(4) Photosynthesis *	32.425	<0.0001	0.0075	0.9312	0.4365	0.5099	52.918	<0.0001	1.2429	0.2916	4.2187	0.0418	0.6517	0.5227
(5) %N **	45.7381	<0.0001	0.116	0.735	7.1946	0.0101	1.9078	0.1597	1.5506	0.2228	0.049	0.8258	1.1267	0.3327
(6)^{13}C	8.0062	0.001	10.2682	0.0024	0.3882	0.5363	4.8037	0.0126	0.4419	0.6455	0.8495	0.3614	1.6651	0.2001

† rank, ‡ yt = y/s, * log(y+1), and ** log (y) transformation to achieve homogeneity of variance.

Discussion

- Elevated temperatures increased height growth and photosynthesis performance at the locations where *P. glauca* is likely to expand its habitat, but decreased these variables in the current habitat of mature forests.
- Under a climate change condition, competition effects become more pronounced.
- Seedlings exposed to extra light, nutrients and water allocated their photosynthates to leaf production rather than height growth.
- Length of the longest leaf decreased over the summer due to leaf turn over.
- Positive values of ^{15}N indicate that the seedlings have not established a symbiotic relationship with mycorrhizal fungi[3].
- All of the seedlings near treeline and most of the ones below treeline suffered from severe nitrogen deficiency.
- ^{13}C near the theoretical values for C_3 plants suggest that the seedlings could discriminate fully against heavy carbon by opening stomata; hence they did not suffer from drought stress when the leaves were formed.
- Neither N concentration nor ^{13}C level fully explained the relation to the variation in photosynthesis rates under the experimental treatments.

References:
1. Denali National Park and Preserve. 2008. Climate-related Vegetation Changes. DENA-FS-016-2008. Denali National Park and Preserve, Denali Park, Alaska.
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3. Hobbie JE, Hobbie EA, Drossman H, Conte M, Weber JC, Shamhart J, Weinrobe M. 2009. Mycorrhizal fungi supply nitrogen to host plants in Arctic tundra and boreal forests: 15N is the key signal. Can J Microbiol 55:84–94

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